

Claim Amendment

1. (Previously Presented) A spring surface treatment method, comprising the steps of:
  - (A) nitriding a surface layer of a spring;
  - (B) projecting hard metal particles having hardness which is lower than the hardness of the nitrided outermost surface layer and is in the range of Hv 500 to 800 and diameters from 200 to 900  $\mu\text{m}$  against the nitrided surface of the spring at a velocity from 40 m/sec. to 90 m/sec., so as to prevent generation of a microcrack in the surface layer by the projection and provide compression residual stress comparatively deep inside the springs; and
  - (C) projecting a number of fine metal particles having a mean diameter of all particles of 80  $\mu\text{m}$  or less, a mean diameter of each particle in the range between 10  $\mu\text{m}$  and 80  $\mu\text{m}$  inclusive, a spherical or near spherical shape having no square portions, specific gravity from 7.0 to 9.0, and hardness which falls in the range between Hv 600 and Hv 1100 inclusive and is equal to or less than the hardness of the outermost surface layer of the spring after nitriding or low-temperature carbonitriding at velocity from 50 to 190 m/sec., while controlling an instantaneous temperature rise limit of an iron matrix excluding the nitride compound layer of the nitrided spring surface layer due to collision to be low enough to cause work hardening in the spring surface layer but not to cause softening due to recovery/recrystallization, thereby effectively work hardening and preventing generation of any microcracks in the surface layer to provide a high compression residual stress and hardness.

2. (Previously Presented) A spring surface treatment method, comprising the steps of:

(A) projecting a number of metal particles having diameters between 10  $\mu\text{m}$  inclusive and less than 100  $\mu\text{m}$ , a mean diameter of all particles of 80  $\mu\text{m}$  or less, a mean diameter of each particle of 10 to 80  $\mu\text{m}$ , a spherical or near spherical shape having no square portions, a specific gravity of 7.0 to 9.0, and a hardness of Hv 350 to 900 against a surface of a spring before nitriding at a collision velocity in the range of 50 m/sec. and 160 m/sec. inclusive so that a temperature rise limit of the surface of the spring due to collision is controlled to be low enough to cause work hardening of an iron matrix of the spring but lower than the point at which recovery/recrystallization may occur so as to prevent generation of any microcracks;

(B) nitriding a surface portion of the spring after step (A);

(C) projecting hard metal particles having hardness which is lower than the hardness of the nitrided outermost surface layer and in the range of Hv 500 to 800, and a grain diameter of 200 to 900  $\mu\text{m}$  against the nitrided surface of the spring at a velocity of 40 m/sec. to 90 m/sec., so as to prevent generation of any microcracks in the surface layer by the projection and provide compression residual stress comparatively deep inside each spring; and

(D) projecting a number of metal microparticles having a mean diameter of all particles of 80  $\mu\text{m}$  or less, a mean diameter of each particle in the range between 10  $\mu\text{m}$  and 80  $\mu\text{m}$  inclusive, a spherical or near spherical shape with no square portions, a specific gravity of 7.0 to 9.0, and a hardness which falls in the range between Hv 600 and Hv 1100 inclusive and is equal to or less than the hardness of the outermost

surface layer of the spring after nitriding or low-temperature carbonitriding at the velocity of 50 to 190 m/sec., while controlling the instantaneous temperature rise limit of the iron matrix excluding nitride compound layer of the nitrided spring surface layer due to collision to be high enough to cause work hardening in the surface layer but lower than a point at which softening due to recovery/recrystallization may occur, thereby effectively causing work hardening and preventing generation of any microcracks in the surface layer to provide a high compression residual stress and hardness.

3. (Previously Presented) A surface treatment method, comprising the step of bombarding hard metal particles having hardness in the range between Hv 350 and 1100, specific gravity of 7.0 to 9.0, a mean diameter of all particles of 80  $\mu\text{m}$  or less, a mean diameter of each particle in the range between 10  $\mu\text{m}$  and 80  $\mu\text{m}$  inclusive, and a spherical or near spherical shape with no square portions, on a surface of a spring with surface layer hardness of Hv 400 to 750, which hardness was obtained by one of low-temperature annealing for removal of macroscopic residual stress after cold forming, quenching and tempering after cold forming, and quenching and tempering after hot forming, at a collision velocity of 50 m/sec to 160 m/sec, while controlling the temperature rise limit of the spring surface layer due to collision to be low enough to cause work hardening in the spring surface layer but not to cause softening due to recovery/recrystallization and preventing generation of any microcracks in the surface layer which may deteriorate fatigue strength, thereby improving the hardness and compression residual stress of the surface layer which is 30  $\mu\text{m}$  to 50  $\mu\text{m}$  or less deep from the surface and resulting in improved endurance of the spring.

4. (Previously Presented) A spring surface treatment method for preventing generation of harmful microcracks in a surface layer of a spring which may deteriorate fatigue strength and for improving especially the hardness and compression residual stress of the surface layer which is 30  $\mu\text{m}$  to 50  $\mu\text{m}$  or less deep from the surface, to improve endurance of the spring, the method comprising the steps of:

(A) projecting hard metal particles having hardness of Hv 350 to 900 and a particle diameter of 200 to 900  $\mu\text{m}$  against the surface of a formed and tempered spring having a surface layer with hardness of Hv 400 to 750 at a velocity of 40 m/sec to 90 m/sec so as to prevent generation of harmful microcracks in the surface layer and provide compression residual stress comparatively deep inside the spring; and

(B) performing the surface treatment method according to claim 3 on the spring surface after step (A).

5. (Previously Presented) A spring surface treatment method according to claim 1 or 2, wherein the particles projected in step (C) of claim 1 or step (A) of claim 2 and the projection conditions of the particles are limited to the following:

hardness of projected particles: initial hardness being Hv 600 to 1100;  
size of projected particles: initial mean diameter of each particle being 10  $\mu\text{m}$  to 80  $\mu\text{m}$ ;  
mean diameter of all particles: 65  $\mu\text{m}$  or less;  
specific gravity of projected particles : 7.0 to 9.0; and  
collision velocity against the spring: 60 m/sec. to 140 m/sec.

6. (Previously Presented) A spring surface treatment method according to claim 3 or 4, wherein the particles used to bombard the spring surface and the projection conditions of the particles are limited to the following:

hardness of projected particles: initial hardness being Hv 350 to 1100;  
size of projected particles: initial mean diameter of each particle being 10  $\mu\text{m}$  to 80  $\mu\text{m}$ ;  
mean diameter of all particles: 65  $\mu\text{m}$  or less;  
specific gravity of projected particles: 7.0 to 9.0; and  
collision velocity against spring: 60 m/sec. to 140 m/sec.

7. (Original) A spring surface treatment method according to claim 1 or 4, wherein in the step (B) of claim 1 or in the step (A) of claim 4, the projection of the hard metal particles having a diameter of 0.2 to 0.9 mm is divided into first-stage projection of comparatively large particles having a diameter of 0.5 to 0.9 mm and second-stage projection of comparatively small particles having a diameter of 0.2 to 0.4 mm.

8--13. (Canceled)

14. (Previously Presented) The spring surface treatment method of claim 2, wherein the metal particles in step (A) are iron-based particles.

15. (Previously Presented) The spring surface treatment method of claim 2, wherein the metal particles in step (A) have a mean diameter of all particles of 65  $\mu\text{m}$  or less.